13914

US ARMY TARDEC/ DARPA

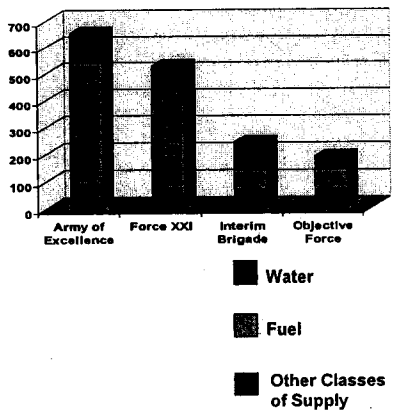
Water Treatment and Harvesting Systems

Dr. Jay Dusenbury
Water Technology Team Leader
Petroleum & Water Business Area
(586) 574-4145 (p)
(586) 574-4123 (f)
Dusenbuj@tacom.army.mil

July 15, 2003

Soldier Water Requirements

- Water weighs ~8.3 pounds per gallon
- 3-4% Water deficit (2-3 quarts) significantly reduces performance (up to 48%)
- 6-8% Water deficit (4-6 quarts) renders a soldier completely ineffective
- Minimum water consumption is 1 gallon/ soldier/ day to 3.5 gallon/ soldier/ day
- Recommended range of 1 to 3.5 gallons equals 8.3 to 29 pounds of water required per day
- Fully developed theater requires 15.6 gallon/ soldier/ day or 129.5 pounds



Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
15 JUL 2003	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
US Army TARDEC/DARPA Water Treatment and Harvesting Systems	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Dr. Jay Dusenbury	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
USA TACOM 6501 E 11 Mile Road Warren, MI 48397-5000	**13914**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	TACOM TARDEC
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

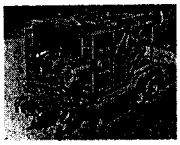
14. ABSTRACT

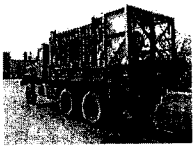
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**17**	

Army Water Purification Systems

- Family of systems based on Reverse Osmosis
- Fielded systems: 600 & 3000 GPH ROWPUs traditional pretreatment/ RO/ Chlorination
  - Treat up to 35,000 TDS
- Developmental systems: 125 & 1500 GPH ROWPUs Integrated Membrane Systems: Microfiltration pretreatment/ RO/ Chlorination
  - Treat up to 45,000 TDS
- Able to purify any source - lake, river, ocean, NBC contaminated - in sufficient quantities BUT
  - Systems have large energy (fuel) requirements
    - 20 to 50 kW-Hr/ Kgal
  - Systems have a large footprint (size/weight)
    - 0.4 to 1 lb/ GPD
  - Systems are a logistics burden - large volume of consumables (filters, membranes, chemicals)
- Purified water must be transported to required location



PWBA - Developmental Efforts

- Military Unique Requirements
- Minimize Size/Weight
- Minimize Logistics
- Maximize Reliability
- Evaluation of Commercial Products
  - RO Pretreatment Studies
    - UF/MF (PDVF)
    - Improved Filtration
    - Automated Screens
  - Seawater materials
  - Cyanide Removal
  - RO/GAC – nerve agent removal
  - Ion Exchange (iodine)
  - Energy Recovery

Modifications and Services for the 3k ROWPU

OBJECTIVE

- To extend the operational life of the RO elements used by the Army from 200 hours to a minimum of 800 hours.
- To evaluate and field improvements to the 3K ROWPU.

BENEFITS

- Current RO elements cost $545 and $908 each for the 6" and 8" elements respectively. Quadrupling the element lifetime should yield a $25 million savings over a 10 year span.
- Testing and implementation to be completed under this program will give TARDEC engineers hands on experience with the latest technologies available in water treatment. This is particularly valuable in future procurement actions.

PROGRAM APPROACH

Evaluate the following specific alternatives available to extend element lifetime:

- New Commercially Available Multimedia Filter Materiel
- Improved Filter Backwash Procedures
- **Coagulant Controller**
- **RO Element Diagnostics Kit**
- **Improved Cleaning Chemicals and Procedures**
- **Hydraulic Modifications (turbo, CF extension)**
- Advanced Cleanable Cartridge Filters
- High Turbidity Add-On Kit
- **MIOX**

STATUS / ISSUES

- Designed and fabricated column test skid. Currently conducting tests @ NFESC.
- Development of 3-Tank Batch controller complete. Currently fabricating test skid for testing.
- Testing of Fuzzy Filter Complete.
- Market surveys completed on centrifuges and cleanable filters. Currently testing cleanable filters @ SANG.
- **Coagulant Controller testing completed.**
- Filter backwash testing completed.
- **Modified 3K ROWPU currently being tested @ SANG.**
- **Market survey of cleaners and preservatives complete. Draft procedural changes completed.**
- **Testing of diagnostic equipment complete.**

Modifications and Services for the 3k ROWPU

Description

- High area, high rejection membranes
  - reduced flux
- Change array configuration and incorporate interstage boost
  - improved flux distribution
  - reduced energy demand (20 to 25%)
- Change high-pressure pump plungers
  - reduced feed flow
  - increased operating pressure

BENEFITS

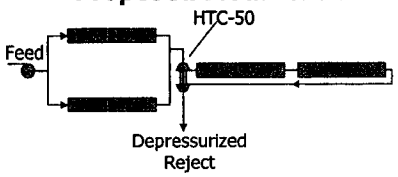
- Improved pretreatment performance due to 25% reduction in feed flow
- Increase RO element life resulting from 1) improved feed water quality, 2) improved flux distribution, and 3) increased driving pressure
- Reduced RO element cleaning
- Fewer multimedia filter backwashes and cartridge filter replacements
- 25% reduction in power requirement and anti-scalant and coagulant
- Increased driving pressure enabling the treatment of higher TDS feed water

STATUS

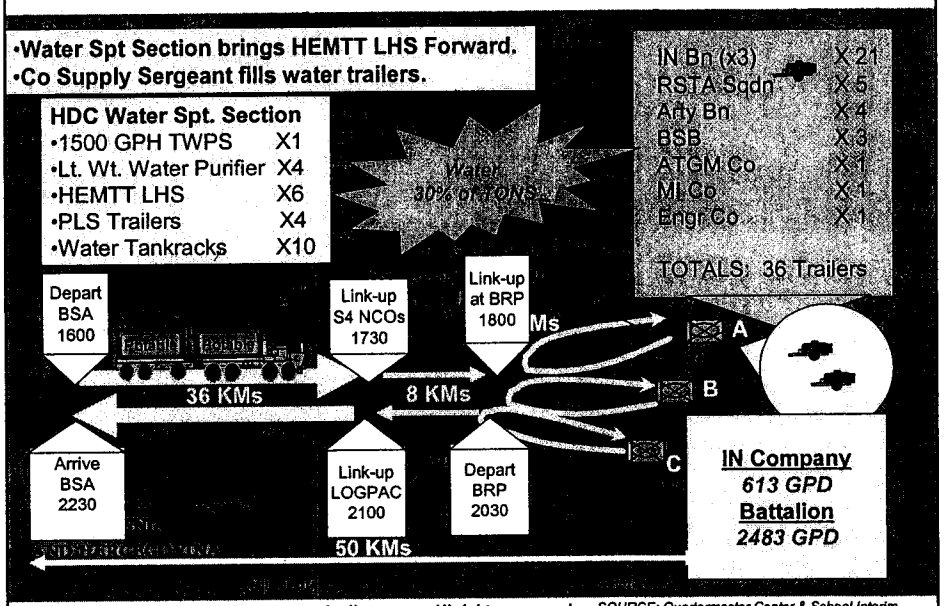
- Completed approximately 500 hours of testing.
- Initial results show increased run time between media filter backwashes and cartridge filter changeouts, and a 20 percent decrease in power consumption.

Current Design

Proposed Modifications



Water Distribution



 SOURCE: Quartermaster Center & School Interim Brigade Brief; MG Proctor

Sustainment Transformation - Water

TARDEC

- Enable Objective Force/FCS 3-7 day Unit of Action (UA) self-sustainment concept
- Un-encumber the FCS and OFW to:
  - Better sustain combat power
  - Increase agility and mobility
- Decentralized water sustainment
- Water generation attacks the fundamental challenge of water logistics - DISTRIBUTION
- Reduce storage requirement to provide space for other warfighter critical materials
- Reduce the logistics footprint

Embedded water generation for individual soldiers and crews cuts the logistics tail

Water Purification, Recovery & Generation Technology

Objective: Reduce the sustainment requirement and logistics footprint associated with water production and distribution.

Thrust Area 1: Create low-power, highly-efficient revolutionary technologies for water purification/desalinization

- Bio-inspired concepts (forward osmosis)
- Reverse osmosis enhancements
- Mixed Oxidant Technology
- New technologies never before explored

Thrust Area 2: Create innovative water "generation" technologies

- Water from air
- Water recovery from exhaust
- Humidity concentration

Teaming with DARPA to leverage basic research and provide integrated technology development & transition strategy – Mesoscopic Machines, Air & Water Purification, and Water Harvesting

DARPA Water Generation Programs

- DARPA Mesomachines Program to Develop "Ice Cube to Fist" Sized Machines for Military Use
- Perfect Fit with Hand-Held Water Purifier
- Water Treatment Research Area Added in FY98 – Evolved into Air & Water Purification Program
- DARPA involved TARDEC up front and early
  - Provided design criteria with military relevance (Hand-held water purifier)
- Maintained close working relationship
  - Project review process
  - Initiation of new concepts, projects & programs
- DARPA initiated new Water Harvesting Program to continue partnership
- Transition Strategy
  - Army Science & Technology Objective
  - Involvement of CASCOM and Program Managers

Individual Soldier Water Purification

MIOX , MesoSystems & MSR

TARDEC

Concept

- Water purification and production becomes increasingly soldier-centric
- Hand-held systems will supply sustaining water at the individual and small unit level

Pacing Technologies

- Electrolytic disinfection (MIOX) uses only salt & water no hazardous chemicals
- Filtration, thin film & monolithic adsorbents
- Reverse and forward osmosis

Payoff

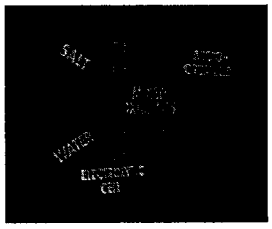
- Reduces dependence on water resupply
- Provides personal purification back-up during early entry, remote site, and emergency operations
- Gives soldier advanced personal water purification technology

Individual Soldier Water Purification

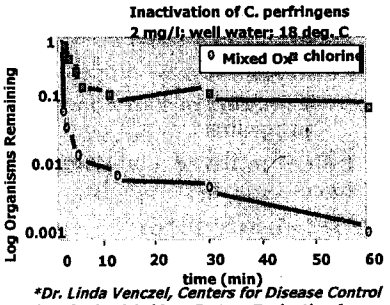
MIOX

TARDEC

- Disinfection Device
  - Requires only salt & water (No Hazardous Chemicals)
  - The disinfectant generation process takes place in-situ
  - Enhanced microorganism inactivation and chem-bio destruction - kills everything
  - Chlorine residual - Military requires detectable chlorine - verifies water is safe



- Pump/Filter/RO System, Man Portable
  - RO is a proven technology, however, current hand-held units are heavy, bulky and require > 4 hrs to produce a 1 day supply of water.
  - Turbidity reduction - EPA limit is 0.3 NTU
  - Total Dissolved Solids (TDS) reduction
  - Easy to operate and light weight, less than 2 pounds
  - Pulsing, advanced spacer design, membrane chemistry, active boundary layer control & novel pump concepts



**Dr. Linda Venczel, Centers for Disease Control (CDC) Mixed Oxidant System Evaluation for Waterborne Disease Prevention in Bolivia, 1993*

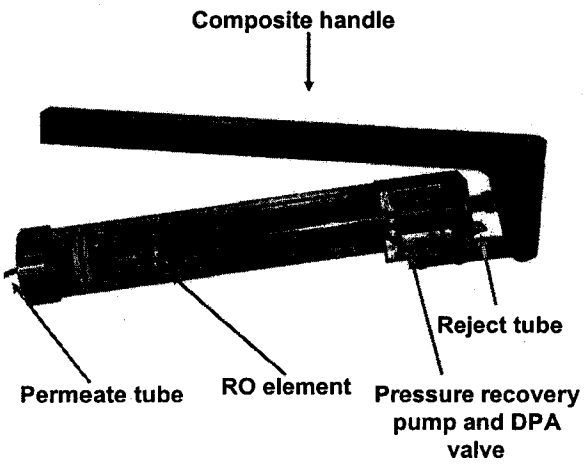
Technology Assessment
Area – MIOX Water Purification

Program Description & Objective:
- MIOX electrolytic disinfection process to replace chlorine disinfectants
- More effective & eliminates the need to transport and store hazardous chemicals
- Miniaturized version to fit in a "pen" or "cap"

Status:
- 100 production prototypes delivered, 10, 000 unit production planned
- Established relationship with commercialization partner for pens to be on store shelves in less than 12 months
- Accepted as a Soldier Enhancement Program (SEP) candidate
- Continued development to incorporate filtration under discussion
- Prototype fabricated for 3,000 GPH ROWPU undergoing testing at TARDEC

Rationale:
- Large-scale system approved by EPA for municipal water treatment facilities
- Required inactivation of viruses, bacteria and spores in 1 to 10 minutes: Hepatitis A virus, Bacillus Antracis (Anthrax), Vaccinia Virus (Smallpox vaccine), Yersinia Pestis (Plague), *E. coli, Cryptosporidium parvum* oocysts
- 5 Pesticides & 1 chemical agent totally destroyed & 2 others were > 50% destroyed
- Completed Air Force Technical Maturity Assessment

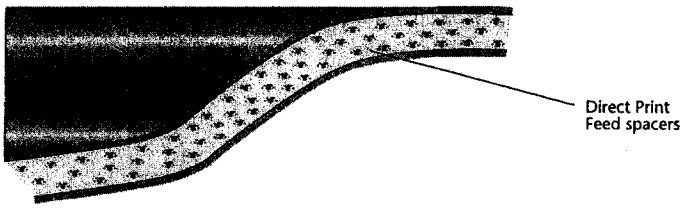
Integrated RO System Prototype



- Innovative pressure recovery valve
- All parts injection moldable with only 3 small metal springs
- Integral RO element with housing - easy and quick change

RO Element Sectional

Direct Print Membrane



Next Generation Hydration System

Program Description & Objective

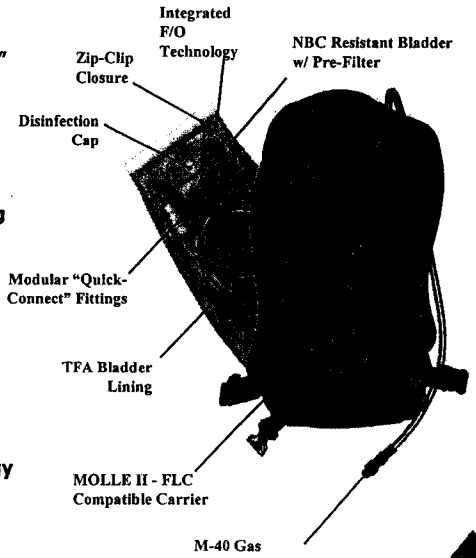
- **Develop an integrated "on the move" purification system**

Assessment Rationale

- **NBC resistance testing available for selected materials**
- **MIOX disinfection tested by independent laboratory demonstrating pathogen destruction**
- **Testing underway for filtration, osmosis, and adsorption technologies**

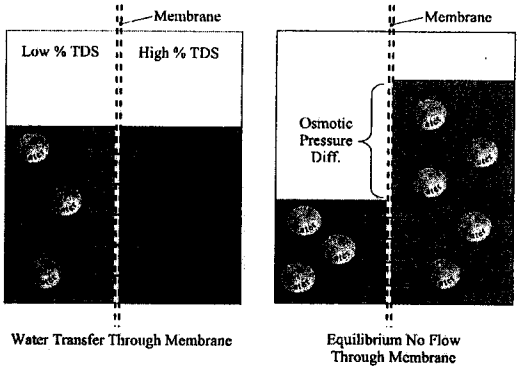
Status

- **Prototype NBC resistant hydration bag and drinking tube undergoing field demonstration**
- **Open architecture to accept technology insertion of filtration, adsorption, and disinfection technology**
- **Engineering design under way for additional capabilities**



Task Description – F/O Bag

- Simple, Lightweight, Compact
- No Power or Pumping Required
- No Filtration of Purification Required
- Hydrophilic – No Fouling
- Self Contained
- Hygienic Delivery



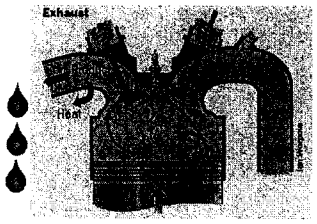
Water From Exhaust

The Lexington Carbon Company, LLC

Concept

- Combustion of 1 gallon of Fuel produces 1 gallon of water
- Capture water from any engine in the battlespace

$$C_9H_{16} + 13O_2 \longrightarrow 8H_2O + 9CO_2$$



Pacing Technologies

- Mesochannel counter-current heat exchanger
- Activated carbon – fiber monoliths & tailored granular
- Designer ion exchange resins

Payoff

- Integrates water production into the platform
- Independence from water distribution and source reduces logistic footprint
- Enable 3 to 5 day operations without need for water resupply

Technology Assessment

Area – Vehicle Water Recovery

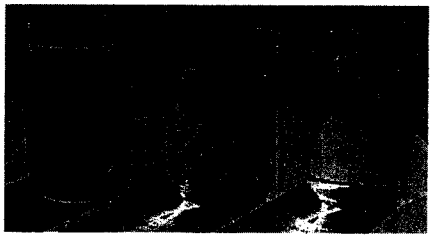
TARDEC

Status:

- **HMMWV mounted breadboard system**
- **Mesochannel countercurrent heat exchanger**
- **Commercial chiller/condenser**
- **Activated carbon and ion exchange water purification columns**
- **Water purification leveraging MIOX and FTC DARPA and STO project**

Rationale:

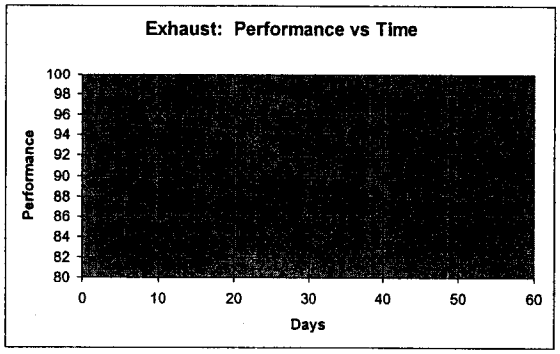
- **Road tests produced 0.5 to 0.6 gallons of water for each gallon of fuel consumed – 2.5 gal/hr**
- **Purified with high fidelity lab breadboard**
- **Integrated vehicle mounted filter designed and fabricated**
- **Purified water tested by independent EPA certified laboratory**
- **Water meets military and EPA drinking water standards**



Exhaust condensate | Particle Filtered Water | Carbon/Resin Purified Water

FTC Purification of Exhaust Condensate

TARDEC



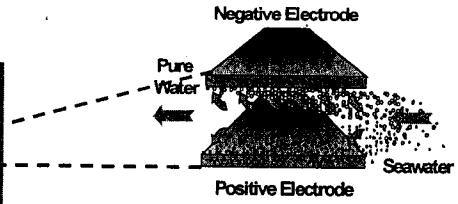
Next Generation Water Purification Systems

Biosource Inc.

TARDEC

Concept

- Flow-Through Capacitors; Capacitive Deionization
- Takes the salt out of water – Not the water out of solution
- Theoretically requires less energy than RO
- Remove radioactive ions (Cs, Sr, etc.)
- Recoverable energy – Capacitors in parallel



Pacing Technologies

- Advanced carbon electrode materials
- Energy management & recovery technology
- Ion management materials

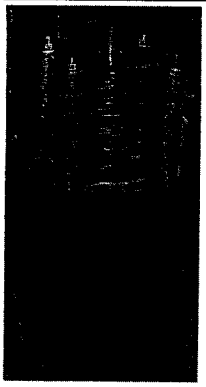
Payoff

- Reduces logistics burden of bulk water purification
- Provides smaller, lighter, more flexible capability
- Allows more agile and responsive battlespace purifiers situated closer to "point of use"

Electrodes

TARDEC

Binder system developed that could be used for any form of carbon



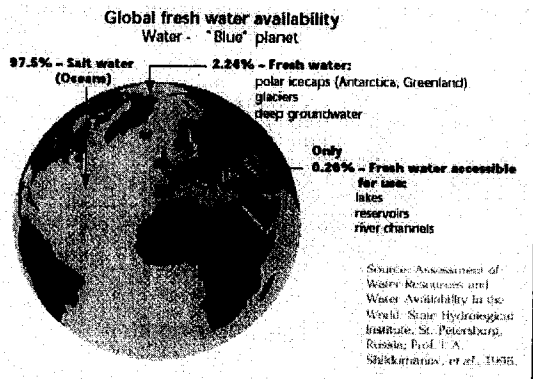
Low ESR
High F/g
Low leakage
control of many physical properties

Property vs performance

Electrodes and spacers developed for with specific properties for different molarities

Why Water From Air

- Only 100,000 km³ is fresh surface water but often in the wrong area or polluted
- World consumption (2000) was 2,800 km³
- 580,000 km³ evaporates and rains/snows every year
- There is 10,000 - 50,000 km³ of water in the air and is more uniformly distributed around the world than any other water source!
- Water from air is pure



DSRC, 7/17/2001

Water From Air

Concept

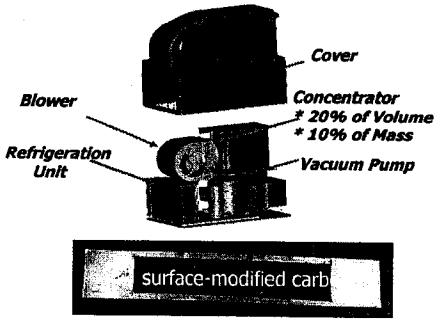
- Harvest water from air in any environment
- Apply in controlled spaces, integrate into systems, or as stand-alone unit generators

Pacing Technologies

- Chemically surface modified activated carbons
- Low energy condensation techniques: elevated pressure, refrigeration, sudden expansion
- Controlling the surface energy of condensing media
- Materials architecture
- Membrane technology

Status

- Laboratory testing of surface modified activated carbon validated concept
- New project initiated based on facilitated membrane transport
- BAA underway for more mature technology approach



Payoff

- Provide platform based (FCSS, OFWS, etc.) and small unit stand alone water production capability
- Provide minimum daily water requirements
- Independence from water distribution & source
- Reduces water storage requirements

Water Harvesting Program Information

- **Program Vision**
  - **Ensure sustainable water supplies to maintain agility and length of deployment for the Objective Force.**
  - **Harvest water from any available source to eliminate 50% of water logistics requirements for *2 to 10,000* warfighters, any place, any time.**
  - **Support homeland defense needs and the needs of strategic, water-deficient regions of the world.**
- **Specific Program Objectives**
  - **Generate 3.5 qts/day/warfighter for 2 to 12 soldiers from apparently nonexistent sources (e.g., water from air or vehicle exhaust) with 15 *Whr/l* efficiency (Task 1).**
  - **Purify/desalinate 3.5 qts/day/warfighter for *2 to 10,000* soldiers from conventional sources (puddle, pond, river, sea) with 3 *Whr/l* efficiency (Task 2).**

Water Harvesting from Vehicle Exhaust
(Stevens Institute of Technology)

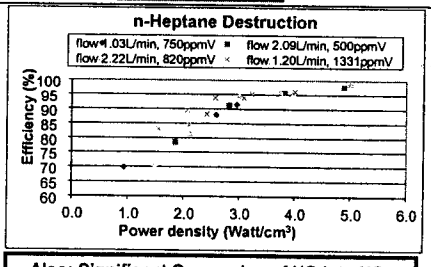
Novel Technology

Harvest potable water from Diesel exhaust using an ambient-pressure plasma to reduce the level of undesirable contaminants to extend the lifetime and capacity of the water recovery system.

Three approaches:

- Plasma treatment of engine air in-take mixture
- Plasma treatment of engine exhaust gas stream
- Combination of plasma pre-treatment of engine in-take mixture and engine exhaust

[redacted]



Also: Significant Conversion of NO into NO_2

Critical Technology Development Areas

Develop plasma reactor that can

- operate reliably in the hot exhaust gas stream
- reduce significantly unburned hydrocarbons and other contaminants in the exhaust gas
- maximize contaminant reduction at minimum energy consumption
- demonstrate a significant increase in the lifetime of the water treatment and polishing system prior to maintenance and/or component replacement

Recent Developments

- Proof-of-principle that plasma modifies combustion process - measurable changes in O2, NO, NO2, and HCs in exhaust emissions in tests with plasma reactor in air in-take of a 16 Hp generator
- Minor effect of in-take treatment on condensate
- Proof-of-principle that plasma modifies the exhaust gas - significant reduction in HCs and increased conversion from NO to NO2 in bench tests with a surrogate exhaust gas mixture

Low-Energy Production of Water from Air (NanoPore, Inc.)

Novel Technology

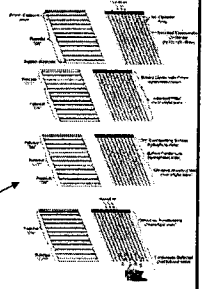
Potable water from atmospheric air without Energy-intensive refrigeration cycle.

Two approaches:

- Variable surface chemistry (hydrophilic-hydro-phobic) in nanoporous membranes with pore sizes of 2 to 20 nm, for adsorption/liquid extraction.
- Electric field gradient/elecro-wetting for enhanced condensation rate, transport and liquid water collection without moving parts.
- High-efficiency, plastic meso-scale heat-exchangers.

Critical Technology Development Areas

- Change the surface chemistry in nanopores from hydrophobic to hydrophilic.
- Graded surface energy coatings by wetting and dewetting.
- Practical electro-wetting electrode structures printed on surfaces to enhance condensation/water collection.



Meeting the Phase 1 Objectives

18-month Go/No-go Milestone

- Produce 1.5 liters/day @ 15 WHr/liter energetics from 25°C, 50% R.H. air.

Specific Goals

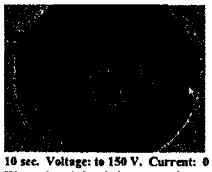
- Rapidly condense and transport water with surface energy varied by electrical energy.
- Move water drops at >1 cm/s with electric field gradient.
- Demo a plastic heat exchanger with flux of >600 W/m^2 with ΔT of 2°C and model fluid flow for optimal water transport.

Recent Developments

- ***Reversible*** wetting in nanopores clearly demonstrated for the first time
- Water drop migration with velocity of >6.7 cm/s via electrowetting demonstrated.
- High performance, light weight plastic meso-scale heat exchanger prototype designed, fabricated, and tested at 1.3 liters/day.

Electrowetting in NanoPores

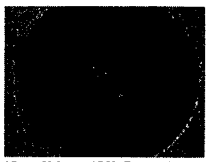
- Electrowetting in 200 nm hydrophobic pores
- Solid evidence of ***reversible*** electrowetting in nanopores!



10 sec. Voltage: to 150 V. Current: 0 mA. Water drop is beaded up on surface, starting to spread due to electrowetting.

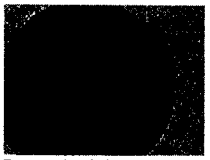
20 sec. Voltage: 15 V. Current limited to 0.4 mA. Shadow in middle of drop continues to increase (~50% of drop).

60 sec. Water drop removed. No transparent region is visible, showing that all the water has come out of the pores



15 sec. Voltage: 15 V. Current limited to 0.4 mA. Water spreads and V decreases as circuit is completed; H_2O enters pores.!

45 sec. Voltage 0 V Darker transparent region has now returned to original color, so all the water has left the pores.

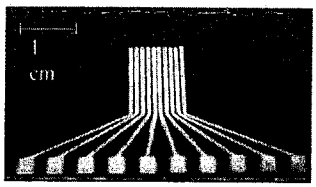


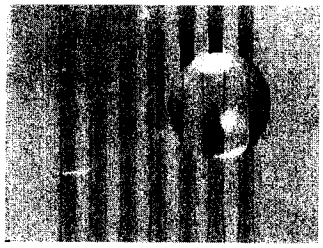
For comparison, hydrophilic membrane after drop is removed, showing the water in the pores, visible as a darker region

NanoPore Low Energy Water from Air

Electromigration of water on a surface

- Enable movement by contact angle gradients via electrowetting
- Test electrode configuration
- Movie of water drop migration with velocity >6.7 cm/s





NanoPore Low Energy Water from Air

Mobile Water Recovery

Santa Fe Science and Technology, Inc

Novel Technology

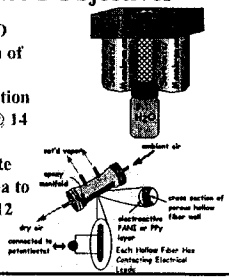
- Polyaniline (conducting polymer) nanostructured hollow fibers as sorbants and membranes.
- Electrical energy converted to chemical energy to favorably modify the energy of desorption.
- Heat transfer and mass transfer coupled in the same hollow fibers.

Critical Technology Development Areas

- Development of PANI hollow fibers with nanoporous outer skin and dense barrier inner skin (lumen).
- Use electrical potential across fibers to modulate sorption/desorption
- Operate refrigeration system between 299-286 K, thus COP_R~20.

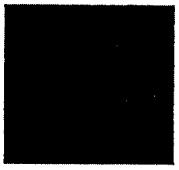
Meeting the Phase 1 Objectives

- Produce 1.5 L/day of H_2O with energy consumption of 15 $W \cdot h \cdot L^{-1}$ (@ 18 mo).
- Create efficient refrigeration system with COP_R~20 (@ 14 mo).
- Use hollow fibers to create modules with surface area to volume ratios >1000 (@ 12 mo).



Recent Developments

- Fabricated first prototype PANI hollow fiber modules with electrical interconnects.
- Developed engineering model for integrated system.
- Identified fibers with stable sorption/desorption properties over multiple cycles.



Portable Low Power Passive Water Purification System

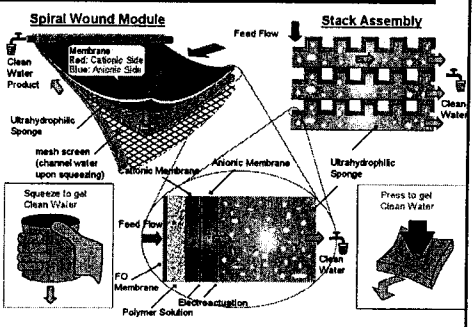
..., condensed diesel engine exhaust, urine, brackish water, etc.

...ternational , Nasotronics, and Facilichem

CRITICAL TECHNOLOGY DEVELOPMENT AREAS

NEW SCIENCE

- **High flux water purification at ambient temperature and low pressure through a custom membrane:**
  - Cationic polymer membrane with cation rejection, self-sterilizing, bacteriostatic and biofouling preventing properties
  - Anionic polymer membrane with facilitated water transport properties and anion rejection properties
- **Ultrahydrophilic sponge on the permeate side draws water through the membrane, collects clean water and releases clean water by "squeezing"**



MEETING THE PHASE 1 OBJECTIVES

Key Milestones

6 mos: **Demonstrate initial multilayer membrane assembly incorporating cationic, anionic and porous electrodes layers**

10 mos: **Demonstrate hydrophilic sponge with 30 wt% water uptake**

18 mos: **Demonstrate a breadboard system that will produce at least 3.5 L clean water per day using no more than 3 Whr/L**

Results to date:

- Demonstrated water purification from brine and brackish water
- Separated essentially residue free water from urine at room temperature and pressure
- Demonstrated electroactuation form membrane antifouling

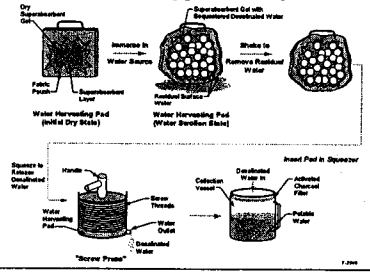
Superabsorbent System for Practical Water Harvesting

Physical Sciences Inc./Kimberly-Clark Corporation

New Science

- **Ampholytic superabsorbent polymers conforming to Donnan membrane equilibria, and constructed to exhibit a double common-ion effect, preferentially absorb pure water from salinated media**
- **Superabsorbent polymers designed to readily *release* water on application of pressure**

Critical Technology Development Areas



Meeting the Phase 1 Objectives

METRIC	18 MONTH MILESTONE
Daily Throughput	> 1.5 l/day
Energetics	0 (hand-powered)
Mass Efficiency	25
Speed per 500 ml	15 min
Purification Effectiveness	Total dissolved solids <500mg/liter
Reusability	3 times per pad
Scalability	10 soldiers
Field readiness	Breadboard system

Recent Developments

- **Synthesis and scale-up (5-50 g) of polyampholytes**
- **Demonstrated screw press for squeezing gels**
- **Preliminary results indicate up to 12-fold desalination of 0.6M NaCl solution (seawater) with polyampholyte gels**
- **Up to 90% of absorbed water released from gels**
- **Initiated synthesis of high charge density gel monomers**
- **System design: gel, fluid distribution layer, fabrics, squeezer**
- **Designed hand-squeezable pouch version of device**

Lorentz Ionic Separation Apparatus (LISA)

New Science

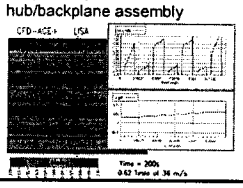
LISA is a deionization process based on established science used in a new fashion:

- Application of Lorentz forces [F = q(v x B)]
- Remove solute (ions) from solvent (water)
  - inherently efficient ion separation approach
  - no need for high pressures
  - ⇒ significantly less energy intensive than RO
- Sweep magnetic lines of flux through solution
  - eliminates need for electrodes (leakage currents)
  - electrostatic shielding effects (energy consumption)
  - ⇒ obviates chief energy loss and power consumption issues associated with electrostatic desal methods
- Potential to remove ***any*** ionic species (e.g., salts, heavy metals, urea, etc.) from any fluidic medium

Approach

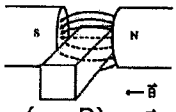
Methods to rapidly move the lines of magnetic flux
(F increases linearly w/ velocity)

Rotating permanent magnets coupled to permeable hub/backplane assembly



Integrated Ion-Selective Cartridge Design

- Salt migration controlled by ion exchange surface chemistries
- Separate deionized and concentrate collection channels



$F_i = q_i(v_B \times B)$

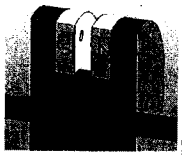
Meeting the Phase 1 Objectives

Computational Modeling
model process and develop baseline system design

Design and test preliminary LISA device
integrated cartridge and magnetic rotor systems

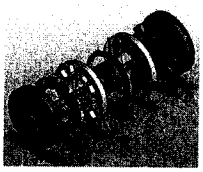
6-month target: proof-of-concept validation
demonstrate desalination possible using Lorentz forces

18-month target (breadboard device):
1.5 liters of water/day from sea water @ E_c ≈3 Whr/l



Accomplishments

- Primary computational models completed; ⇒ CFD results confirm LISA concept works
- Proof-of-concept magnetic rotor apparatus designed and fabricated
  - 10 pairs of permanent FeNdB magnets; max field ≈1T
- Test ion-exchange cartridges designed and fabricated
  - Low pressure recirculation system
- LISA concept has been experimentally validated
  - sodium ions reversibly driven from DI channel to concentrate channel
  - measurements provided by independent OSU water quality lab



Proof Of Principle

- **Modeling demonstrates LISA achieves one order drop within 4 minutes & 0.4 meters**
- **12" Rotor test apparatus will allow experimental proof of the basic Principle of ion separation using swept magnetic flux lines.**